SECTION 17

17.1 Why use a UPS System?

Some of the more obvious needs for standby power are observed in such instances as area wide "blackouts" and various "brownouts" which occur many times in large cities during periods of peak power usage. While these are very troublesome and expensive in terms of loss of work and property, they are not as major of a concern to industry as are the more frequent power fluctuations.

In the past 10 to 20 years, most of our industry in the United States, as well as around the world, has become more automated. With this dependence on machine and computer to perform the functions of process control for an entire plant, has come the necessity of providing a more reliable source of power than is normally available from the electric utilities.

This need can be better understood with a few specific examples:

1) When a bolt of lightening strikes a utility power distribution line, it will result in a loss of power for approximately 15 cycles (1/4 second). This is observed when lights dim and then return to normal.

2) When an automobile hits a utility pole breaking the power lines, a small area may be without power until the lines can be repaired. However, a much larger area may be without power for 5 to 30 seconds while the automatic controls at the utility feeder station shed loads from certain power grids and reconnect them to other grids

within their own generating facilities or those of a neighboring utility.

We could discuss the power fluctuations caused by deliberate voltage reduction (brownout), switching transients, generator failure, distribution failure, etc., but suffice it to say, that it is not uncommon to have fluctuations on the utility line many times a day of sufficient magnitude and duration to be a major concern to many industrial processes even though they may not be observable to the human eye.

Additional to the power fluctuations on the utility feeder lines, are those caused internally within the plant itself. These may be caused by such things as starting or stopping large motors, equipment breakdowns, accidents, etc.

When facility power is interrupted, we immediately think of the people-related needs such as emergency lighting and elevator power. However, if the building is without lights for a few seconds, there would probably be little, if any, people related problems. Long before this presented a problem, many other very expensive processes may have ceased to operate.

In many industrial applications, a change in voltage of only 15% to 20%, or a change in frequency of only 2% to 3% may cause the operation to shut down. For some loads, these fluctuations only need to occur for 1/2 to 1 cycle (.008 to .016 seconds for 60 Hz power).

A computer may "dump" its memory and may require many hours to be reprogrammed; a process control in a refinery may shut down and require 1 to 3 hours for restart; a fiber spinning operation may shut down and require hours to clean out the solidified polymer from the spinneret before restart can be accomplished; or the critical life support systems of a hospital's operating and intensive care units may go off the line and result in the loss of life.

Because of these and many other requirements for reliable standby power, more and more facilities are being equipped with emergency back-up power systems.

These systems typically include a large bank of storage batteries, a battery charger for DC power back-up, and an inverter if back-up AC power is needed.

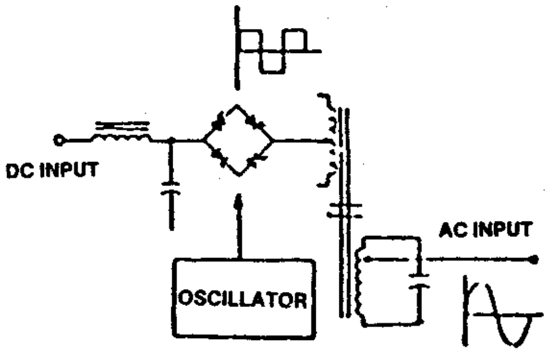
17.2 Different types of Solid State UPS Systems

UPS systems are often referred to according to their design type (Ferroresonant, Quasi-Square Wave, PWM or Stepped Wave). At other times, the various UPS systems are referred to according to their use type (inverter prime "on-line" or line prime "standby"). We will give a brief description of the various design types followed by an explanation of the difference in an on-line and a standby application.

17.2.1 Ferroresonant

This approach is by far the simplest, and perhaps the most reliable, requiring the fewest amount of active components. A typical 1ø ferroresonant inverter consists of one power state (3ø uses three) to produce a square wave AC voltage. The square wave is fed through a ferroresonant constant voltage transformer (CVT). The CVT contains a resonant circuit which in conjunction with leakage reactance performs the AC filtering function. Furthermore, the CVT is inherently a current limiting device, in that it will provide no more output current than its capacity. Since the frequency of the square wave input is fixed, the output voltage is maintained at a constant level due to the saturating elements in the CVT. Thus, the CVT inherently provides in one device, AC filtering, current limiting and regulation.

FERRORESONANT (CVT) INVERTER

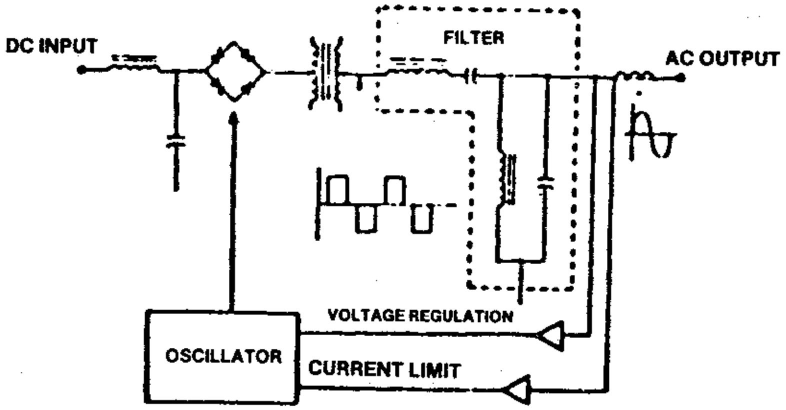


Since all regulating and current limiting functions are inherent, the need for control feedback loops is eliminated. The absences of these feedback loops provides a very reliable and stable voltage that is fixed and not subject to change due to component failure. The ferroresonant inverter is insensitive to non-linear or high crest factor loads making this type of system ideally suited for computer backup.

17.2.2 Quasi-Square Wave

This approach is the simplest which uses true electronic (rather than magnetic) regulation. It consists of two square waves offset to produce a zero-third harmonic waveform. These are generated from a 4-SCR bridge for 1ø or a 6-SCR bridge for 3ø inverters. Regulation is achieved by changing the regulation of the second square wave with respect to the first, thus varying the pulse width and amplitude of the overlap and the RMS value of the ultimate output sine wave. A series/parallel L-C filter is employed to filter harmonics from the 5th up. The performance characteristics of this approach are generally limited by filter design and impedance. Well designed quasi-square wave inverters can meet all of the critical parameters previously discussed on a highly reliable basis.

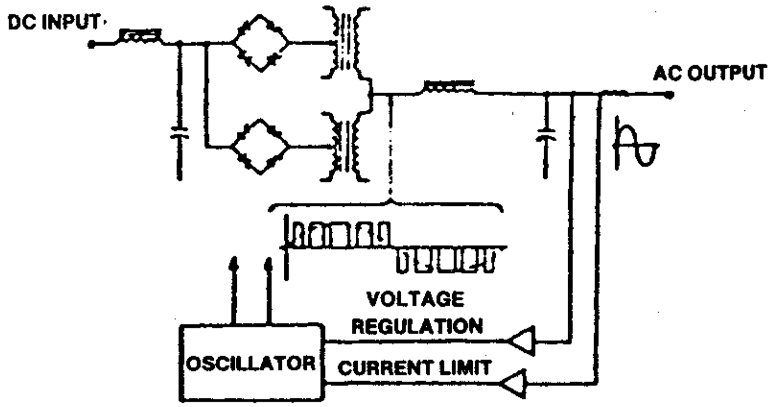
QUASI-SQUARE WAVE INVERTER



17.2.3 Pulse-Width Modulation

The manufacturers of this inverter design approach like to characterize it as "state of the art". In fact, it's been around for many years. Like the others, it has its own set of advantages and disadvantages. Essentially, a square wave is generated at a comparatively high frequency, 1.2 KHz or so. Its duty cycle is varied so that at the zero crossing point of the AC waveform, it is on a very short time compared with the off-time; and at the waveform crest, the on-time to off-time ratio is very high. The number of pulses per half-cycle depend on the frequency employed, as does the inverter output performance. Obviously, with many pulses, precise output voltage control and a low distortion output are easily achievable. With only a few pulses, the unfiltered waveform is comparable to that of a quasi-square wave system. In the design and selection of pulse-width modulated inverters, there is a distinct tradeoff. If one uses a higher frequency system, 2 KHz or above, high performance including transient response and efficiency can be achieved, but the component (SCR) state of the art is being pushed and reliability is severely compromised. At lower frequencies performance is no better than less sophisticated approaches, but because the control logic is complex in this approach regardless of frequency, the result is a complicated system with no major performance enhancement.

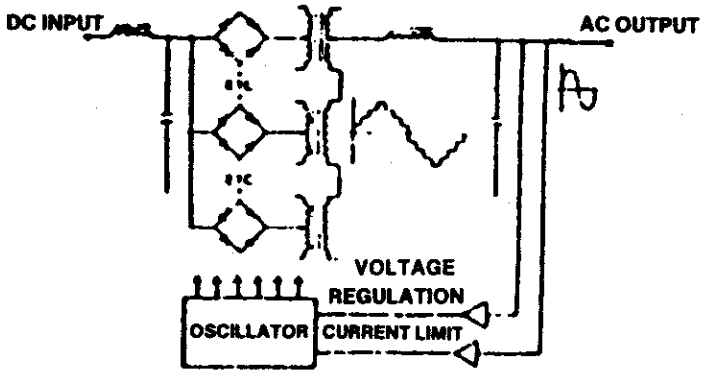
PULSE WIDTH MODULATED INVERTER



17.2.4 Synthesized or Stepped Waveform

Employed primarily in very large 3ø inverters, this approach generally uses four each 3ø 6-SCR bridges, divided into two pairs of two bridges each. Each pair produces a 3ø 12-step waveform. The two 12-step waveforms are then phase-shifted in respect to one another to regulate the ultimate output voltage. If they are 180° out-of-phase, there is zero output as they cancel out. When they are exactly inphase, there is maximum output. Because the 12-step waveform inherently eliminates harmonics below the 11th, this approach needs only a simple low pass output filter to achieve a very low distortion output sine wave. And transient response is excellent. These systems, however, are very complex and have the lowest predicted MTBF of all.

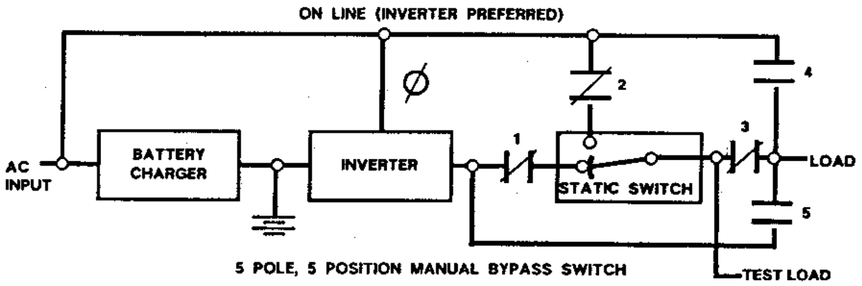
SYNTHESIZED OR STEPPED WAVEFORM



17.2.5 Inverter Prime (On-Line)

For an AC load where maximum back-up protection is desired, an on-line system should be used.

The on-line system contains four major components: a constant voltage current-limited battery charger, a storage battery, a static inverter and a static transfer switch as illustrated in the following diagram.



MODE	SWITCH POSITION 1	2	3	4	5
ALTERNATE SOURCE POWER LOAD (S.S. TEST)	X	X		X	
ALTERNATE SOURCE POWER LOAD (S.S. ISOLATED)				X	
INVERTER POWER LOAD THRU S.S. (NORMAL)	X	X	X		
INVERTER POWER LOAD (S.S. ISOLATED)					X
INVERTER POWER LOAD (S.S. TEST)	X	X			X

Under normal operation, the AC line power feeds the battery charger which "float" charges the battery and provides input power to the static inverter. The inverter, through the static transfer switch, supplies power to the AC load. Since this is the normal mode of operation, any power disturbance that may occur in the AC line will not be transmitted to the AC load since the battery charger, battery, and inverter input filter are very good buffers which absorb these disturbances. With this system, the AC output of the inverter will, therefore, be of better quality than the normal AC line.

If a fault condition should occur in any of the branch circuits of the AC load which exceeds the inverter capability, the voltage of the current-limited static inverter will begin to drop. The static switch will then transfer the AC load from the inverter to the AC line, which provides the high current to clear the fault in the branch circuit. The static switch then retransfers the load back to the inverter. With this type of system, The AC load will transfer from the inverter to the AC line when the inverter either malfunctions or is overloaded.

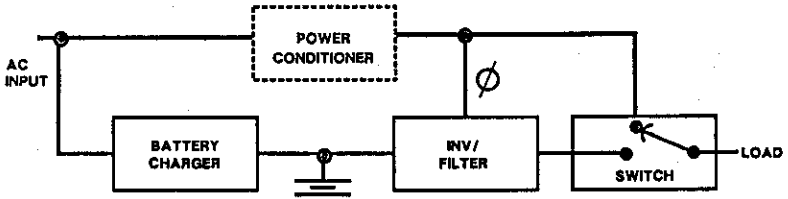
A manual bypass switch, mounted on the door of the inverter, is used to allow the protected load to be switched to the AC line, isolating the inverter and static switch for routine maintenance. The manual bypass switch has overlapping contacts to permit bypass of the load without any interruption.

17.2.6 Line Prime (Standby)

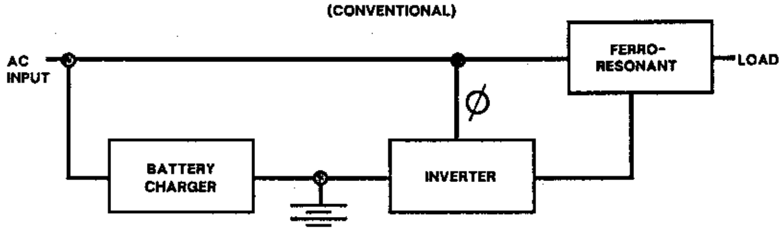
The standby system is normally configured identical to the on-line system. However, because the charger is never recharging the battery plus powering the fully loaded inverter, it can be a smaller capacity charger. (When the utility line is available to power the charger, it is also powering the load).

In a standby system, the load is transferred to an idling inverter when the utility fails. If the load is near the full load capacity of the inverter, the transient response of the unit could be as much as 30% to 40% for 1 to 3 cycles. Because of this, it is not uncommon to eliminate the static switch and replace it with an electromechanical switch (2 to 6 cycle transfer time).

STANDBY UPS



(CONVENTIONAL)



(TRI PORT)

17.3 Different Types of Transfer

17.3.1 Static Transfer

The static transfer switch is a solid state device configured from power SCR's. When the power to the load is determined to have deviated from specification in amplitude or frequency, the control portion of the switch will initiate a transfer signal to the SCR's that are "Off" and gate them "On". The auxiliary power source will then supply the load and commutate the previous side of the switch to "Off". When the line source deviates from its preset frequency more than specified, the inverter will release it and operate "open loop" from its own internal oscillator. In this open loop mode, the automatic transfer switch will not operate.

The switching time on a static transfer switch is virtually zero because it is a make-before-break device and the switching action is accomplished by causing an electron to move 2 to 3 microns across the semiconductor junction.

It should be understood, however, that for the transfer to be made, a failure condition on the load must be sensed. There is probably enough inductance in the line that if it were to "open" or "short" there would be a finite time lag in being able to observe it with even the most sensitive of instruments. Because the sine wave voltage is going from a positive peak through zero, to a negative peak and back through zero to positive 60 times per second, it is observed that one could not say the supply has failed because its output is zero, for this happens 120 times per second. One also cannot say the voltage is collapsing, for this also happens 120 times per second. Therefore, the load line must be continuously monitored for a change in frequency, a long term deviation in voltage and a short term change in voltage. Because of the sensing time requirement, it is probably more accurate to speak of 1/4 cycle transfer because, if the line should begin to fail at the moment it is at a positive or negative peak, it could be as much as 1/4 cycle (.004 seconds on a 60 Hz supply) before an actual "failure" could be determined.

17.3.2 Electromechanical Transfer

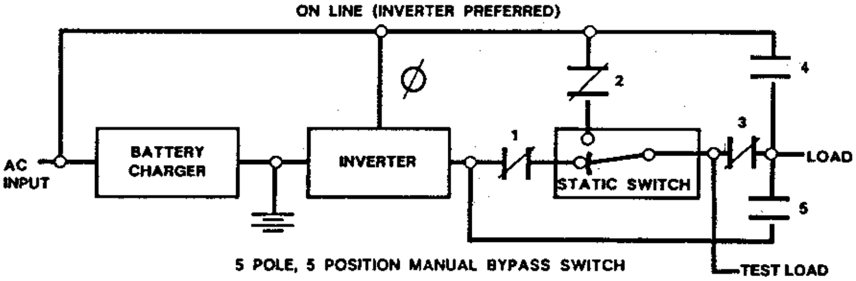
An electromechanical transfer switch is simply a break-before-make power relay or contactor, depending upon the amount of the power being switched. Because of the relay action, there will be a loss of power for 2 to 6 cycles during transfer.

17.3.3 Manual Bypass Switch

The manual bypass switch is a multi-pole, make-before-break manually operated rotary switch which will isolate the static switch and inverter from the auxiliary line for maintenance.

Attention should be given to the type of maintenance bypass (MBP) switch used as well. First, the MBP switch should be a make-before-break device. Usually a 4-pole, 2-position switch is employed. This provides isolation to perform maintenance on the static switch but does not allow for actual static switch testing under load, after repair prior to powering the system load.

By changing the 4-pole, 2-position MBP switch to a 5-pole, 5-position switch (15-pole, 5-position for 3ø) and adding a "test load" terminal to the output of the static switch, the static switch can be tested under load after repair prior to bringing the system back on-line.



5 POLE, 5 POSITION MANUAL BYPASS SWITCH

MODE	SWITCH POSITION 1	2	3	4	5
ALTERNATE SOURCE POWER LOAD (S.S. TEST)	X	X		X	
ALTERNATE SOURCE POWER LOAD (S.S. ISOLATED)				X	
INVERTER POWER LOAD THRU S.S. (NORMAL)	X	X	X		
INVERTER POWER LOAD (S.S. ISOLATED)					X
INVERTER POWER LOAD (S.S. TEST)	X	X			X

17.4 Fuse Coordination

Branch circuit fusing from a "soft" source is, of course, a very interesting problem. This problem is made even more interesting when the source is a semiconductor device because "high speed semiconductor fuses", which react fast enough to protect the semiconductor are very expensive. In fact, many times they cost more than the device being protected. Therefore, there is usually some resistance to using these high speed semiconductor fuses for branch fusing.

Because of the self-protecting feature of the inverter through its current limit feature, the inverter output voltage will collapse when it is overloaded. If a static switch is in the system, the unit will transfer the load to the auxiliary source and assuming it is a stiff source, branch circuit fusing would be identical to normal (non UPS) applications.

Note: It must be noted that the static transfer switch must be large enough to accommodate any inrush to be experienced; otherwise, it becomes the fuse.

In multiple load applications without a static switch, the inverter would probably burn a small load off of the line should it malfunction and go to ground. However, if the inverter was already operating at near full capacity and one branch malfunctioned to ground, there would not be sufficient energy left to burn it off and the end result would be the UPS would go into a "Current Limit" mode and operate at reduced output voltage. This would, of course, protect the inverter, but the loads would shut down due to under voltage.

17.5 UPS Specification

UNINTERRUPTIBLE POWER SYSTEM (UPS)

SPECIFICATION

No. CPMC-UPS-060190-GB

CONTENTS

1.0 SCOPE

2.0 SYSTEM OPERATION

3.0 DESIGN BASIS

4.0 ELECTRICAL CHARACTERISTICS

5.0 MAINTENANCE

6.0 FACTORY TESTING

7.0 DOCUMENTATION REQUIREMENTS

8.0 PACKING AND SHIPPING

9.0 DETAIL DATA SHEET

1.0 SCOPE

1.1 This specification covers the requirements for the design, materials, and fabrication of an uninterruptible power supply (UPS).

1.2 The UPS shall be designed to deliver regulated, uninterrupted and transient-free AC power to the critical load, under normal and abnormal conditions of the utility power line.

1.3 It shall consist principally of a solid state, regulated battery charger, solid state inverter, static switch, and manual bypass switch. It shall also include the necessary synchronizing circuitry, overcurrent protection, alarms, controls, and instrumentation. A detailed equipment list is given in Section 9 of this specification.

2.0 SYSTEM OPERATION

2.1 Normal Operation

Power for the critical loads is supplied from the inverter through the static switch. Normal operating DC power for the inverter is obtained from the AC line through the regulated battery charger. The frequency of the inverter AC output is synchronized to the normal AC power line frequency.

2.2 Loss of Normal AC Power

Upon loss of normal AC power to the charger, inverter DC operating power is supplied from a battery bank (specified separately). The inverter will operate within specified frequency and voltage limits using internal regulation with no interruption to the output waveform. The inverter shall automatically shut down when the battery voltage falls below the "end of discharge" voltage specified in Section 9.

2.3 Return of Normal AC Power

The regulated battery charger will again automatically supply power from the normal AC power line to the inverter. The inverter will automatically synchronize to the AC power line and maintain uninterrupted power to the load without disturbance. The battery charger will also recharge the battery in preparation for future AC power line outages.

2.4 Static Transfer to Bypass

The static transfer switch shall automatically transfer the load to the bypass AC power source upon any of the following conditions:

a. Overload or short circuit at the load
b. Inverter shutdown due to a discharged battery
c. Inverter failure

For momentary faults, the static switch shall retransfer the load to the inverter when the fault clears. It shall be equipped with a switch to allow for automatic or manual operation of this retransfer. Transfers shall occur with no interruption of power to the load, and less than $\frac{1}{4}$ cycle of voltage deviation at worst case. Transfers to bypass shall not occur when the inverter output is not synchronized to the bypass AC power source unless the inverter output fails.

2.5 Manual Bypass

The manual bypass switch allows transfer of the load directly to the bypass AC source without interruption, permitting removal of power to the UPS power modules for maintenance.

3.0 DESIGN BASIS

3.1 Codes and Standards

3.1.1 Unless noted otherwise, the design, fabrication, testing and performance of the UPS system shall be in accordance with the latest edition of the following applicable codes and standards:

National Electrical Manufacturers Association (NEMA)
American National Standards Institute (ANSI)
Institute of Electrical and Electronic Engineers (IEEE)
National Electrical Code (NEC)
Underwriters Laboratories (UL)

3.2 Environmental

3.2.1 The uninterruptible power supply shall be suitable for operation within a ventilated area, within a temperature range of -20 to 40°C. with a maximum relative humidity of 95% (non-condensing).

3.3 General Mechanical

3.3.1 The equipment shall be housed in NEMA-1 enclosure(s), allowing top or bottom cable entry, and shall be suitable for side-to-side installation, requiring front access only for servicing. Access shall be through hinged door(s). Free-standing cabinets shall be fitted with removable lifting eyes, and ground lugs.

3.3.2 Convection ventilation is the preferred method of cooling. If forced ventilation is necessary, redundant fans with fan failure alarm are required. Easily replaceable air filters are also required with force ventilated enclosures. Vendor shall state method of cooling in his proposal. The charger, inverter, static switch and manual transfer switch shall preferably be contained in the same enclosure. If separate enclosures are required, they shall be of the same height and color.

3.3.3 The enclosures shall be fabricated from steel. The metal shall be thoroughly cleaned using a phosphate dip preparation. Zinc chromate primer shall be applied at a thickness of 2 mils, and baked at 350° to cure. The finish coat shall be 2 mils, ANSI #61, light gray enamel baked at 350° to cure.

3.3.4 Metal or insulating barriers shall be provided to isolate the major components and to prevent arc propagation during fault conditions.

3.3.5 All transformers and wiring shall be copper. Terminals shall be provided at each component enclosure to accept adequately sized interconnecting cables.

3.4 General Electrical

3.4.1 The charger, inverter, and static switch shall be new and of solid state design. Power components shall be sized at 150% of required capacity. The charger and inverter shall be current limited to prevent damage to the unit in the event of short-circuit or overload condition.

3.4.2 Control cards shall have plug-in, or screw terminal connections to the wiring harness (no solder connections allowed).

3.4.3 All alarm relays provided shall have one set of form-C dry contacts wired to terminals for customer connection.

3.4.4 The preferred type of alarm lamps are light emitting diodes (LED's). A push-to-test circuit must also be included. Vendor shall state in his quotation, the type of lamps offered.

3.4.5 Wiring to control and alarm cards shall be labeled at card terminal. All wiring shall be neatly routed; wiring to doors shall be have protective wrap.

3.5 Battery Charger

3.5.1 The battery charger shall be of the dual rate, current limiting type, and shall regulate its DC output voltage to ± 1% of nominal, from 0-100% load, and with an AC power line input of ± 10% voltage, and ± 5% frequency. The required AC input & DC output voltages are specified in Section 9.

3.5.2 The charger shall limit its output current to no more than 110% of its continuous current rating, and shall provide this current limit at full voltage.

3.5.3 The charger shall maintain its output ripple to 2% RMS, unless otherwise specified in Section 9.

3.5.4 The battery charger shall be sized by the vendor to:

a. carry the entire inverter load
b. carry any DC load specified in Section 9
c. recharge the battery to 90% capacity, within the recharge time specified in Section 9, while carrying loads a. and b. above

3.5.5 The battery charger DC output shall be isolated from the AC input, and shall not allow current reversal upon charger failure.

3.5.6 The charger shall have a current walk-in feature to prevent a sudden load to the charger feeder circuit.

3.5.7 If a manual equalize timer is specified in Section 9, it shall replace the standard float/equalize switch, and shall initiate battery equalization/recharge manually, returning the battery to float voltage after the preset time. If an automatic equalize timer is specified in Section 9, it shall replace the standard float/equalize switch. It shall initiate battery equalization/recharge either manually or upon failure of AC input to charger (with 10 second delay), and shall return the battery to float voltage after the preset time.

3.5.8 The charger efficiency, at full load, shall not be less than 90%. The vendor shall state charger efficiency in his quotation.

3.6 Static Inverter

3.6.1 The inverter may be of ferroresonant, PWM, or synthesized waveform design. The vendor shall state the design type in his quotation.

3.6.2 The inverter shall have a sinusoidal waveform output, with no more that 5% total harmonic distortion (THD), and no more than 3% distortion per any single harmonic.

3.6.3 The inverter shall regulate its AC output voltage to ± 2% of nominal, and shall regulate its frequency to ± .25%, from 0-100% load, and over the full range of DC input voltage.

3.6.4 The inverter shall maintain synchronism with the bypass AC power line when AC input power is available, but shall not exceed a slew rate of one hertz per second (1 Hz./Sec.), and shall break from synchronism to run on its own oscillator when the bypass AC input deviates in frequency by more than ± 1 Hz.

3.6.5 Three-phase inverters (when specified) shall permit a load unbalance of up to 35% of total KVA rating, while maintaining voltage regulation of ± 5% or better.

3.6.6 The inverter shall be rated to carry full, continuous load at a power factor of .8 (leading or lagging), and 80% load at unity power factor.

3.6.7 The inverter must be capable of withstanding overloads of 125% for 10 minutes, or 150% for 15 seconds.

3.6.8 The inverter efficiency at full load, shall not be less than 80%. The vendor shall state inverter efficiency in his quotation.

3.6.9 The inverter shall have a maximum voltage deviation of ± 10% for 0-100% load change with full recovery within 25 mS, and shall have a maximum voltage deviation of ± 5% for 0-50% load change with full recovery within 16 mS.

3.7 Static Transfer Switch

3.7.1 The static transfer switch shall automatically transfer the load to the bypass AC power source upon any of the following conditions:

a. Overload or short circuit at the load
b. Inverter shutdown due to a discharged battery
c. Inverter failure

For momentary faults, the static switch shall re-transfer the load to the inverter when the fault clears. It shall be equipped with a switch to allow for automatic or manual operation of this re-transfer. Transfers shall occur with no interruption of power to the load, and less than ¼ cycle of voltage deviation at worst case. Transfers to bypass shall not occur when the inverter output is not synchronized to the bypass AC power source unless the inverter output fails.

3.7.2 The static switch shall be capable of carrying 1000% overload for 1 cycle to handle clearing of short circuits.

3.7.3 Automatic transfer to bypass shall occur whenever inverter output voltage falls to 90 percent of normal.

3.8 Manual Bypass Switch

3.8.1 A 5-position, make-before-break, manual bypass switch (with load test terminals) shall be provided to:

a. transfer the load directly to the bypass AC source--bypassing the static switch and inverter, or

b. transfer the load directly the inverter--bypassing the static switch, and Bypass AC source.

Each bypass position shall have a corresponding test position, to allow connection of a test load at the test terminals and transferring the static switch under load prior to bringing it on-line after static switch maintenance.

4.0 STANDARD FEATURES

4.1 Battery Charger

4.1.1 The following standard features shall be supplied for the battery charger, unless otherwise specified in Section 9.

a. DC Voltmeter
b. DC Ammeter
c. Float/Equalize Switch
d. Easily accessible, Float and Equalize Potentiometers
e. AC Input Circuit Breaker
f. DC Output Circuit Breaker
g. Low DC Voltage Alarm Relay & Lamp
h. Ground Fault Alarm Relay & Lamps (1-pos, 1-neg)
(on units with 120 VDC bus, or greater)
i. AC & DC Surge Protection

4.2 Inverter and Static Switch

4.2.1 The following standard features shall be supplied for the inverter and static switch, unless otherwise specified in Section 9.

a. AC Voltmeter (Load)
b. AC Ammeter (Load)
c. DC Input Circuit Breaker
d. AC Output Circuit Breaker
e. Bypass Source Input Fuse
f. Static Switch Manual Initiate Switch
g. Manual/Auto. Static Switch Retransfer Selector Switch
h. Static Switch "On Inverter" Alarm Relay & Lamp (green)
i. Static Switch "On Bypass" Alarm Relay & Lamp (red)
j. "Inverter/Bypass In-Synch." Lamp (green)
k. Load Test Terminals
l. Lamp Test Switch

5.0 MAINTENANCE

5.1 Test points shall be provided to allow easy adjustment and servicing. All adjustment and tests shall be possible with the use of a standard volt-ohm-millimeter and oscilloscope.

5.2 The enclosure(s), shall require front access only for servicing.

6.0 FACTORY TESTING

6.1 Standard factory testing shall include the following items. Any additional testing required shall be specified in Section 9. Witness of testing by customer, if required, shall be specified in Section 9. All testing shall be confirmed and documented on test report forms and supplied with system documentation package.

6.2 Functional Test - Power UPS unit with all proper input voltages and attach load to output, simulating a typical installation. Perform a complete functional test on all accessories specified to verify their correct operation. This test shall include, but not be limited to:

a. Circuit Breakers
b. Meters
c. All Alarm Relays & lamps
d. Fans (if installed)

6.3 Isolation Test - Ohmmeter/megger tests shall be performed on all input and output terminals to insure proper isolation from the cabinet.

6.4 Voltage Regulation - Adjust input voltage to lowest specified level and record unloaded input and output voltages. Also perform test under full-load conditions. Verify that results are within tolerance.

6.5 Charger Ripple - Record charger AC ripple at battery terminals with charger at full load with nominal AC input voltage. Retest with no load.

6.6 Inverter Oscillator Test - Close inverter DC breaker; check oscillator waveform.

6.7 Inverter Synchronization Test - With inverter operating, apply AC voltage to bypass input to verify correct operation of synchronization circuit.

6.8 Inverter Low DC Input Shutdown - Verify that inverter will automatically shutdown at the "end-of-discharge" voltage specified in Section 9.

6.9 Inverter Output Frequency - Verify that frequency remains in tolerance from 0-100% load variations.

6.10 Inverter Output Oscilloscope Tests - Using an oscilloscope, read and verify the correct waveform for the following conditions (pictures of waveforms may be requested in Section 9).

a. Distortion at from 0-100% load
b. Static Switch Transfer Interruption

7.0 DOCUMENTATION REQUIREMENTS

7.1 Final documentation as follows shall be included as standard. Any additional documentation required shall be specified in Section 9.

a. UPS Unit Data Sheet
b. Outline Dimension Drawings
c. Charger Electrical Schematic
d. Charger Bill of Material with priced spare parts
e. Charger Test Report
f. Inverter Electrical Schematic
g. Inverter Bill of Material with priced spare parts
h. Inverter Test Report
i. Static Switch Electrical Schematic
j. Static Switch Bill of Material with priced spare parts
k. Static Switch Test Report
l. UPS Unit I.O.M. Instructions

A minimum of four sets of above documentation shall be assembled for each UPS system. One set shall ship with the equipment, two sets shall be sent to the project engineer (or specified documentation control officer), and one set shall be maintained at the factory (in their files), which can be located for engineering review (by referencing the equipment, by purchase order name and number, project name and number, or equipment serial number).

Any additional sets required will be specified in Section 9.

7.2 Maintenance procedures shall be written to enable a trained technician to systematically troubleshoot the entire system, locating faulty circuit cards, plus faulty transformers, SCR's, diodes, current transformers, meters, relays, resistors and capacitors not located on circuit boards. Test points or suitable reference points shall be provided to facilitate use of an oscilloscope or voltmeter, to display the waveforms and voltage. A written systematic diagnostic procedure must fully describe how to utilize the voltages, circuit diagrams, and other maintenance information to locate faulty circuit boards or other faulty major components not located on the circuit boards.

8.0 PACKING and SHIPPING

8.1 Unless otherwise specified in Section 9, the vendor shall prepare and protect all equipment for domestic shipment. This may include crating, special bracing, protecting against extended storage if specified in Section 9 and any other measures required to assure delivery, handling and storage in good condition.

8.2 Each shipping container or crate shall be equipped with lifting facilities so that it may be easily unloaded and handled by fork-lift or lifting eyes.

8.3 Each major item shipped shall be properly marked or tagged as described in Section 9.

9.0 DETAIL DATA SHEET

9.1 Special Environmental Requirements:

____

9.2 Battery Data:

Battery Type:
☐ Wet, 20-year* Lead Calcium
☐ Sealed, 20-year* Lead Calcium
☐ Sealed, 10-year* Lead Calcium
☐ Wet, 25-year* Nickel Cadmium
* battery prorated warranty life
☐ Other ________________

Nominal Voltage: _______ VDC
The battery will provide:
full load input power to the below referenced inverter,
plus an additional DC load of _______ amps,
for _______ ☐ minutes ☐ hours,
to an end voltage of _______ VDC (_______ v/c)
at _______ ° ☐ C. ☐ F.

☐ *Battery Breaker, 2P ☐ *Fused Battery Disconnect, 2P
* in separate, NEMA-1, wall-mount enclosure:
_______"W x _______"D x _______"H, _______ lb.

9.3 Charger Data:

Input: _______ VAC, _______ Ø, _______ Hz.
Output: _______ VDC
☐ 30 mV ripple; ☐ other ripple _______
Battery Recharge Time: _______ Hours

[ ] Manual Timer; [ ] Automatic Timer
[ ] AC Failure Alarm Relay & Lamp
[ ] High DC Voltage Alarm Relay & Lamp
[ ] DC Failure Alarm Relay & Lamp
[ ] Ground Detection Alarm Relay & Lamps
[ ] AC Pilot Lamp
[ ] Equalize Lamp
[ ] Other

9.4 Inverter Data:

Input: ________ VDC
Output: ________ VAC, ________ ø, ________ Hz.
[ ] Alternate Source Breaker (in lieu of fuse)
[ ] FM (Inverter)
[ ] Bypass Unavailable Alarm Relay and Lamp (red)
[ ] Overtemperature Alarm Relay and Lamp (red)
[ ] Battery Breaker Open Alarm Relay and Lamp (red)
[ ] Battery Discharging Alarm Relay and Lamp (red)
[ ] Manual Bypass Switch in "Bypass" Alarm Lamp (red)
[ ] Fan Failure Alarm Relay and Lamp (red) (if applicable)
[ ] Audible Alarm with Manual Reset
[ ] Mimic Bus on UPS Door
[ ] Other

9.5 Testing:

[ ] Witness Testing Required
[ ] Certified Test Reports Required
[ ] Other

9.6 Documentation:

[ ] Preliminary Documentation Required
(per section 7.1, parts a,b,d,g,j)
_______ sets prints, _______ sets reproducibles

[ ] Approval Documentation Required
(per section 7.1, parts a,b,d,g,j)
_______ sets prints, _______ sets reproducibles

[ ] Final Documentation Required
(per section 7.1, parts a thru l)
_______ sets prints, _______ sets reproducibles

[ ] Inverter Oscillograms Required
[ ] Other Documentation Required

9.7 Special Shipping Preparation / Tagging Instructions:

____

____

____

____

* * End of Specification * *

17.6 Sizing the UPS System

In order to determine the proper UPS power capacity, one must first determine the total worst case load (AC voltage, amps rms and power factor). Also, we will need to determine the load starting sequences and if the inverter will be sized to handle all inrushes or if they will be handled by bypassing to the alternate source.

The UPS KVA requirements will simply be the sum total of all of the worst case loads (including inrushes) the UPS must power.

To properly size the battery for a UPS system, one of the formulas shown below should be used.

TO SIZE THE UPS BATTERY:

$$I = \frac{\text{KVA (PF) (1000)}}{\text{(VOLTAGE (EFF) (} \quad \text{)}}$$

I = DC AMPS FROM BATTERY

KVA = INVERTER KVA

PF = LOAD POWER FACTOR

VOLTAGE = (VOLTS/CELL @ END VOLTAGE) (NO. OF CELLS)

EFF = EFFICIENCY @ % OF LOAD

( ) = ANY OTHER EFFICIENCIES
(i.e. S.S., other transformers, etc)

OR

$$\text{KW/CELL} = \frac{\text{KVA (PF)}}{\text{(EFF) (NO. OF CELLS)}}$$

17.7 Start Up

After the system is installed, the next question is who will provide system startup. The following checklist will be helpful in this endeavor.

TYPICAL ENGINEERING STARTUP

VISUALLY CHECK UPS & BATTERY FOR PHYSICAL DAMAGE OR ABNORMALITIES.

RECORD BATTERY ROOM TEMPERATURE
RECORD UPS ROOM TEMPERATURE

BATTERY

RECORD BATTERY MANUFACTURER
RECORD BATTTERY CELL TYPE
RECORD BATTERY AH CAPACITY
RECORD NUMBER OF CELLS
RECORD SYSTEM LOAD PROFILE
RECORD SPECIFIED FLOAT VOLTAGE
RECORD SPECIFIED EQUALIZE (RECHARGE) VOLTAGE
RECORD SPECIFIED SPECIFIC GRAVITY (WET VENTED ONLY)
AFFIX CELL NUMBERS
RECORD PILOT CELL TEMPERATURE
CHECK CELL POLARITY
RECORD THE SPECIFIC GRAVITY OF EACH CELL (WET VENTED ONLY)
RECORD THE OPEN CIRCUIT VOLTAGE OF EACH CELL
RECORD INTERCELL CONNECTION RESISTANCE WITH MICRO-OHMMETER*

* IF ANY READING VARIES FROM THE AVERAGE BY MORE THAN 10%:
DISCONNECT, CLEAN, RECONNECT, RE-TORQUE AND RE-GREASE THESE SPECIFIC CONNECTIONS

RECORD FINAL INTERCELL RESISTANCE
CLEAN AND WIPE DRY
RECORD TOTAL BATTERY OPEN CIRCUIT VOLTAGE

UPS

CHECK ALL CABLE CONNECTIONS
CHECK BATTERY POLARITY CONNECTIONS
CHECK FOR EXCESSIVELY HEATED AREAS
POWER UP UPS AND BATTERY (WATCH METERS AND LISTEN FOR UNSTABLE CONDITIONS)
TEST LAMPS AND HORN
PERFORM A COMPLETE FUNCTIONAL TEST INCLUDING CHARGER, INVERTER, STATIC SWITCH AND MANUAL BYPASS SWITCH
SIMULATE POWER FAILURE
ASSESS METER AND INDICATOR READINGS
RECORD BATTERY FLOAT VOLTAGE
RECORD BATTERY EQUALIZE (RECHARGE) VOLTAGE
CONNECT SYSTEM TO CUSTOMERS LOAD
PERFORM SYSTEM LOAD TEST OF BATTERY (ONLY AT CUSTOMERS REQUEST)
RECORD INDIVIDUAL BATTERY CELL OR BLOCK VOLTAGE UNDER LOAD
PERFORM COMPLETE FUNCTIONAL TEST UNDER LOAD
SIMULATE POWER FAILURE UNDER LOAD
RECORD ALL METER READINGS
RECORD ALL BREAKERS, SWITCH AND INDICATOR POSITIONS
TOP UP BATTERY WITH DISTILLED WATER AS NEEDED (WET VENTED ONLY)
PLACE CHARGER IN "EQUALIZE" (RECHARGE) FOR 24-72 HOURS

If you decide to perform the start up yourself, the following list of test equipment will be needed. Spare parts should be available and a detailed IOM should be studied.

TEST EQUIPMENT NEEDED

DIGITAL VOLTMETER
MICRO-OHMMETER
INFERRED SCANNER
OSCILLOSCOPE (POSS.)

RECOMMENDED SPARE PARTS

FACTORY RECOMMENDED SPARE PARTS SHOULD BE AVAILABLE

NOTE: A COMPLETE INSTALLATION, OPERATIONAL AND MAINTENANCE (IOM) MANUAL INCLUDING INTERCONNECT DIAGRAM, ELECTRICAL SCHEMATICS AND TROUBLE SHOOTING PROCEDURES SHOULD BE STUDIED PRIOR TO BEGINNING STARTUP.

Although the solid state UPS system is much more common place than it was 10 to 15 years ago, it is our experience and opinion that start-up service is usually worth the relatively small cost necessary to obtain it, especially for larger systems.

The problem is in coordinating total system start-up with the factory, but this provides a good deal of peace of mind when accomplished. It is also important to understand that the interface between the factory field service engineer and the plant maintenance personnel can be very valuable. Most field service engineers are pleased to spend a few hours explaining the system to those responsible, after the start-up is completed.